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COMPARATIVE STUDY OF PHYSICOCHEMICAL COMPOSITION, ANTIOXIDANT ACTIVITY AND MICROBIOLOGICAL CHARACTERISTICS OF NECTARINE POWDER OF BULGARIAN ORIGIN AND FLOUR MIXTURES WITH ITS PARTICIPATION

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Abstract

Local food research contributes to the improvement of the food culture of the nation and to the development of new products. The current scientific paper presents a comparative study of the physicochemical composition, antioxidant activity and microbiological characteristics of the nectarine powder and flour mixtures with its participation.

The flour powder was obtained by drying the sliced nectarines through a heat pump dryer in selected conditions - 8h at 420C and finely they were grounded using a blender. The floury mixtures were made with 70% of basic flour (white wheat flour, whole wheat flour, oat whole flour and Einkorn flour) and 30% of nectarine powder. International Standards such as ISO, AOAC and national standard methods (Bulgarian State Standards) were used for all of the chemical and microbiological analyses. The antioxidant activity was determined using the DPPH (1,1-diphenyl-2-picrylhydrazyl radical), ABTS (2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid), FRAP (Ferric Reducing Antioxidant Power Assay) and CUPRAC (CUPric Reducing Antioxidant Capacity) methods and they were expressed in mMTE/g DW.

The results shown that the nectarine powder own a rich composition and can add as a source of bioactive compounds for improve the nutritional values of the based flour of white wheat, whole wheat, oat and Einkorn. The new obtained floury mixtures were designed for four different sponge cake production with specific nutritional values.

In summary, the presented data a great possibility for developing new products with bettered micro and macro composition based on the local fruit powder. And remarked the importance of thorough research on the regional food product.

***Key words**: Nectarine, Physicochemical composition, Antioxidant activity, Microbiological characteristics, bioactive compounds, functional food.*

1. Introduction

Comparing scientific papers that examine the main product and its derivative products is important for understanding the potential benefits of the main product in different food systems. This type of comparison helps researchers understand the physicochemical and functional properties of the product, how it performs in different food systems, and can guide the development of new food products with improved quality and functionality. Additionally, comparative studies help to evaluate the potential benefits of using the main product in different food formulations and how they affect human health.

There have been several studies on the importance of analysing the physicochemical and functional properties of food products and their derivatives. For example, Souza *et al.*, [1], compared whole and defatted Brazil nut flour to evaluate their use in bakery products. Kaur *et al.*, [2], compared the physicochemical properties of flour from six quinoa cultivars for gluten-free bread-making. Trachoo *et al.*, [3], compared flour blends containing rice flour, taro flour, and okara flour for gluten-free bread-making, and Shi *et al.*, [4], compared potato starch and potato flour for gluten-free bread-making. These studies showed how comparative characterization of food products and their derivatives can guide the development of new food products with improved quality and functionality. Overall, these studies demonstrated the importance of comparative characterization of food products and their derivatives to assess their potential applications and benefits in different food systems. Such studies can guide the development of new food products with improved quality and functionality, which can have significant implications for human health and nutrition.

While there have been analyses on the antioxidant activity of nectarine and flour mixtures, it is unclear if any specific analyses were done on the flour mixtures involving nectarine powder. Several analyses have been done on the antioxidant activity of nectarine and flour mixtures. However, there are published research papers on flour mixes involving nectarine powder, such as a study by Sękulska-Nalewajko *et al.*, [5], which found that adding nectarine powder to wheat flour increased the antioxidant activity of bread. It is important that flour mixtures have increased antioxidant activity because antioxidants have been shown to have numerous health benefits, such as reducing the risk of chronic diseases like heart disease, cancer, and diabetes [6]. Additionally, antioxidants can help to prevent or delay the oxidation of fats in food, which can improve the shelf life of food products [7].

Although the abstract provided information on the microbiological indicators of nectarine and flour mixtures, including the total count of mesophilic aerobic and facultative anaerobic microorganisms, yeasts and molds, *Escherichia coli*, *Salmonella* spp., coagulase-positive staphylococci, and coliforms, according to the scientific literature research, it is unclear if any specific analyses were done on the microbiological indicators of flour mixtures involving nectarine powder.

Preliminary research has not found any information on a comparative study of the physicochemical composition, antioxidant activity, and microbiological parameters of Bulgarian-origin nectarine powder and its flour mixtures.

2. Materials and Methods

2.1 Materials

2.1.1 The nectarines powder

Nectarines were bought from different stores in Plovdiv, Bulgaria. The fruits was washed and dried. The stone was removed and then the nectarines were cut into slices that were 3.0 mm thick or less. The fresh slices were replaced in a single layer on a heat pump dryer for 8 hours at 42 ^{0}C. After the drying process, the slices were finely milled with a blender into powder [8].

2.1.2 White wheat flour and nectarines powder mixture

A flour mixture of 70% white wheat flour and 30% dried and powdered nectarines was composed. White wheat flour (Flour Extra made by Goodmills Bulgaria LTD) was purchased in local stores in Plovdiv, Bulgaria. The physicochemical composition of white wheat flour according to the label was: energy value of 1439 kJ/339 kcal; 0.9 g fat, of which 0.3 g saturated; 70.2g carbohydrates, of which 3.1 g sugars, fibres 1.5 g, and 11.8 g protein [9].

2.1.3 Whole wheat flour and nectarines powder mixture

A flour mixture of 70% whole wheat flour and 30% dried and powdered nectarines was composed. Whole wheat flour (Whole grain flour made by Goodmills Bulgaria LTD) was purchased in local stores in Plovdiv, Bulgaria. The physicochemical composition of white wheat flour according to the label was: energy value of 1368 kJ/324 kcal; 1.9 g fat, of which 0.4 g saturated; 56.1g carbohydrates, of which 3.4 g sugars, fibres 12.56 g and 14.3 g protein [10].

2.1.4 Oat flour and nectarine powder mixture

A flour mixture of 70% oat flour and 30% dried and powdered nectarines was composed. The oat flour is produced by Ecosem Bulgaria LTD and purchased in local food market in Plovdiv, Bulgaria. The physicochemical composition of oat flour according to the label was: energy value of 1690 kJ/404 kcal; 9.1 g fat, of which 1.6 g saturated; 70.0g carbohydrates, of which 0.8 g sugars and 14.7 g protein [11].

2.1.5 Einkorn flour and nectarines powder mixture

A flour mixture of 70% einkorn flour and 30% dried and powdered nectarines was composed. Einkorn flour was produced by Eci-2002 LTD and purchased at a local food market in Plovdiv, Bulgaria. The physicochemical composition of einkorn flour according to the label was: energy value of 364 kcal; 2.97 g fat; 69.86 g carbohydrates; and 14.67 g protein [12].

2.2 Methods

2.2.1 Physicochemical composition, antioxidant activity and microbiological load

The physicochemical composition, antioxidant activity, and microbiological load of the samples were determined using established standard methods. The ash content was evaluated using ICC Standard No. 104/1 [13], and the Kjeldahl method was used to measure the total nitrogen content in the samples, which was then multiplied by 6.25 to convert to crude protein [14]. The total lipids [15], and crude fiber [17] were evaluated using standardized methods, while reducing sugars were determined by the Luff-Schoorl method. Carbohydrates were determined using AOAC Method 988.12 (44.1.30) [16], and moisture content was measured by drying 5 g of flour at 105 ^{0}C to constant weight [14]. The antioxidant activity was determined using a method described by Bogoeva *et al.*, [18], and the microbiological load was assessed by determining the: total number of mesophilic aerobic and facultative anaerobic microorganisms [19], molds and yeasts [20], *Escherichia coli* [21], *Salmonella* spp. [22], and coagulase-positive staphylococci [23], and coliforms [24].

All tests were conducted in triplicate, and the data presented are mean values and standard deviations.

3. Results and Discussion

3.1 Biochemical composition

Knowing the approximate biochemical composition of the nectarine powder and its comparison with flour mixtures with its participation, presented in Table 1, can provide several insights. The levels of carbohydrates, proteins, fats, and other nutrients present in nectarine powder with that of flour mixtures can demonstrate how it can contribute to a balanced diet. Also, it can help in determining the functional properties of nectarine powder when used in flour mixtures. For example, the presence of carbohydrates and fibre in nectarine powder can influence the texture, moisture content, and water activity of the flour mixture. Knowing these properties can help in optimizing the formulation of baked goods, such as cakes, biscuits, and bread, where nectarine powder is used as an ingredient.

Results are reported as calculated on dry basis: Oat flour mixture - 90.82 ± 0.18%; Whole wheat mixture - 91.82 ± 0.22%; Einkorn flour mixture - 91.17 ± 0.10%; Wheat flour mixture - 89.82 ± 0.09%; and Nectarine powder - 94.13 ± 0.78%.

Nectarine powder is characterized by high carbohydrate content and low fat and protein content [25]. Fiber and ash content will vary between cultivars, growing conditions and preparation method [26]. If the nectarine powder was prepared with the peels, the fiber and ash content would be higher [25; 27; and 28]. As can be seen from the data in the Table 1, the type of flour to which the nectarine powder is added affects the biochemical characteristics of the mixture. The total carbohydrate content in the mixture with whole grain flour are the smallest (70.50 ± 1.65%, Table 1), but the same mixture also has the highest total fiber content (9.46 ± 0.10%). With the exception of nectarine powder, the blend of white flour and nectarine powder had the greatest total carbohydrate content (76.83 ± 1.05%) which is normal given that the rest of the flours used to make the mixtures are whole grain. Since the nectarine powder has a very low total fat content (0.25 ± 0.04%), the fat content of the flour mixtures is mainly influenced by the fat contained in the flours themselves. Of the indicated mixtures, the highest fat content was reported for the mixture of whole grain oat flour and nectarine powder. As reported from other authors' oats are considered to be one of the most nutritious whole grain cereals owing to their high fiber and protein content, along with good concentration

Table 1. Biochemical composition of nectarine powder (NP) and selected flours, enriched with nectarine powder previously characterized in literature. Comparative view

	Total carbohydrates, %	Total lipids, %	Crude protein, %	Crude fiber, %	Ash, %	Reference:
Nectarine powder (NP)	86.33 ± 0.31	0.25 ± 0.04	1.98 ± 0.16	2.13 ± 0.08	4.87 ± 0.00	**[8]**
Wheat flour + 30% NP	76.83 ± 1.05	0.91 ± 0.17	8.10 ± 0.30	1.72 ± 0.12	2.34 ± 0.22	**[9]**
Whole Wheat flour + 30% NP	70.50 ± 1.65	1.84 ± 0.12	10.30 ± 0.48	9.46 ± 0.10	3.20 ± 0.59	**[10]**
Whole Oat flour + 30% NP	74.40 ± 0.86	3.71 ± 0.72	9.98 ± 0.07	6.21 ± 0.10	3.49 ± 0.19	**[11]**
Whole Einkorn flour + 30% NP	74.63 ± 0.55	1.91 ± 0.13	10.43 ± 0.27	8.02 ± 0.31	3.16 ± 0.24	**[12]**

of vitamins and minerals [29; 30]. When compared to pure grain flours, the chemical analysis reported by the authors revealed a reduction in the quantity of protein and lipids, as well as an increase in the amounts of total carbohydrates and ash content, and these changes could be caused by the substitution of nectarine powder, which has a low amount of protein and lipids and a high amount of total carbohydrates [27; 28; and 31]. It should be noted that when nectarine powder was obtained, the nectarines' skins were not removed.

3.2 Antioxidant capacity

Understanding the chemical composition, antioxidant activity, presented in Table 2, and microbiological load of nectarine powder compared with flour mixtures with its participation can provide insights into its nutritional value, functional properties, safety, and shelf life when used as an ingredient in baked goods.

Of the reported flour mixtures in Table 2, the mixture of oat flour and nectarine powder had the greatest antioxidant activity by any of the methods used. An exception was observed with the ABTS method, where the antioxidant capacity of the blends with spelt flour, oat flour and whole wheat flour were similar. In the study by Eskicioglu *et al.*, [32], antioxidant dietary fibers are naturally present in cereals such as oat, wheat and rye. Oats include phenolic components represented by flavonoids and phenolic acids, which have strong antioxidant activity and B-vitamin levels [33; 34]. Consumption of whole grain products has been linked to a lower incidence of diabetes and cardiovascular diseases [35 - 37]. Overall, the combination of nectarine powder and grain flour has improved nutritional content and may exhibit distinct qualities in dough formation and baking product quality, as well as being a unique product with stronger antioxidant activity [38].

3.3 Microbiological assessment

Comparing the microbiological load of nectarine powder with that of flour mixtures can help in determining its safety and shelf life. If the nectarine powder has a lower microbial load than the flour mixtures, it can extend the shelf life of the baked goods. The reported data on the microbiological evaluation of the flour blends are presented in Table 3.

From the data presented, the absence of pathogenic microflora is evident. The flours have low water activity

Table 2. Antioxidant capacities of nectarine powder (NP) and selected flours, enriched with nectarine powder previously characterized in literature. Comparative view

	Antioxidant capacity, mMTE/g dw				Reference:
	DPPH	ABTS	FRAP	CUPRAC	
Nectarine powder (NP)	23.76 ± 0.05	1.83 ± 0.01	1.03 ± 0.02	0.59 ± 0.02	**[8]**
Wheat flour + 30% NP	0.45 ± 0.05	0.46 ± 0.01	0.18 ± 0.01	0.43 ± 0.01	**[9]**
Whole Wheat flour + 30% NP	2.40 ± 0.03	0.52 ± 0.01	0.24 ± 0.01	0.75 ± 0.02	**[10]**
Whole Oat flour + 30% NP	5.53 ± 0.04	0.53 ± 0.01	0.31 ± 0.01	1.24 ± 0.01	**[11]**
Whole Einkorn flour + 30% NP	1.48 ± 0.05	0.53 ± 0.00	0.23 ± 0.01	0.75 ± 0.05	**[12]**

Table 3. Microbiological characteristics of nectarine powder (NP) and selected flours, enriched with nectarine powder previously characterised in literature. Comparative view.

	Total count of mesophilic aerobic and facultative anaerobic microorganisms, CFU/g	Yeasts and molds, CFU/g	Coliforms, CFU/g	Coagulase-positive staphylococci, CFU/g	*Escherichia coli*, CFU/g	*Salmonella* spp.,/25 g	Reference:
Nectarine powder	$3.2x10^3$	$4.5x10^2$	$1.2x10^3$	<10	<10	N/D	**[8]**
Wheat flour	$9.3x10^3$	$6.0x10^2$	<10	<10	<10	N/D	**[9]**
Whole wheat flour	$7.7×10^5$	$1.6×10^4$	$3.0×10^5$	<10	<10	N/D	**[10]**
Oat flour	$5.0×10^4$	$8.5×10^2$	$6.7×10^3$	<10	<10	N/D	**[11]**
Einkorn flour	$6.7×10^4$	$2.0×10^3$	$1.0×10^4$	<10	<10	N/D	**[12]**

Legend: N/D: Not detected.

and are considered to be a microbiologically safe product. However, throughout the manufacturing and milling processes, flours are subjected to microbial contamination [33; 39; and 40]. Highest value of total count of mesophilic aerobic and facultative anaerobic microorganisms, yeasts and molds, and coliforms was reported for the whole wheat flour mix - 7.7 x 10^5, 1.6 x 10^4, and 3.0 x 10^5 respectively. This could be due to contamination in the environment, improper processing, or unsuitable conditions during storage. The lowest levels of the same parameters are reported for nectarine powder. The provided results show that the flour combinations are microbiologically safe.

4. Conclusions

- This study conducted a comparative analysis of the physicochemical composition, antioxidant activity, and microbiological characteristics of nectarine powder and flour mixtures with its participation.
- Nectarine powder was found to be rich in bioactive compounds and can improve the nutritional value of the flour mixtures. The new floury mixtures can be used for sponge cake production with specific nutritional values.
- The study emphasizes the importance of local food research in improving the food culture of the nation and developing new products with better micro and macro compositions. Overall, the results provide a great opportunity for developing new products with improved nutritional value based on the local fruit powder.

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